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INFLUENCE OF SOIL FLY ASH AND SOIL-BAGASSE ASH MIXTURE ON HYDRAULIC CONDUCTIVITY OF SOILS

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ABSTRACT

In this paper, an attempt has been made to investigate the influence of addition of fly ash and bagasse ash to two types of soils in different proportions, on hydraulic conductivity of soil ash mixture. Two types of locally available soils of class CL-ML (Soil-1) and SP (Soil-2) were used. Fly ash (FA) was collected from thermal power plant, Panki, Kanpur and the bagasse ash (BA) was collected from sugar mill Sultanpur. Different proportions of FA and BA varying from 0% to 75% were added to both types of soils. The hydraulic conductivity of soil-ash mixtures was determined by using falling head permeability test in the laboratory. From the analysis of results, it is inferred that hydraulic conductivities of soil-2 with bagasse ash and fly ash follow a more or less similar decreasing trend of hydraulic conductivity with increase in percentage of ash contents. On the other hand, a reverse trend is observed with soil-1 mixed with fly ash and bagasse ash showing an increasing trend of hydraulic conductivity with increase in bagasse ash content. But the rate of increase in hydraulic conductivity is observed relatively slower in case of soil-1 replaced by FA than BA in different proportions. The results of the present study do have practical utility in the field of geotechnical engineering constructions.

Key Words: Bagasse Ash, Falling Head Permeability Test, Fly Ash, Hydraulic Conductivity, Local Soils.

I. INTRODUCTION

Due to ever-increasing demand of power for development purposes, the production of fly ash is rising rapidly, while generating electric power by thermal power plants in India. The increase in the production of fly ash and its disposal in an environmental friendly manner is increasingly becoming a matter of global concern. The behaviour of structure depends on the properties of soil on which they are constructed. For the structure to be safe and sound, they should be built on good and sound soils.

Fly ash is a pozzolana, a siliceous material which in the presence of water reacts with calcium hydroxide at ordinary temperatures to produce cementitious compounds. Fly ash possesses a wide range of chemical composition depending on the nature of coal and processes of coal burnt [1].Because of its spherical shape and pozzolanic properties, fly ash is useful in cement and concrete applications. Disposal of this enormous amount

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of fly ash requires huge land, and spaces. Therefore, the best way of disposing fly ash is to utilize it, after converting it into a non hazardous material through an economic process.

On the other hand, bagasse is the residue obtained after the juice is extracted from sugar cane in the sugar milling industry. When this bagasse is burnt the resultant ash is bagasse ash. Bagasse ash is the residue remaining after incineration during the bagasse combustion process. The ready availability of bagasse as a by-product of sugar production has always made it an attractive fuel for the sugar industry and this practice tends to be the most economical method of disposal.

Therefore the best way of disposing fly ash and bagasse ash is to utilize it with some additives and converting it into a non – hazardeous material. Various researchers have utilized the fly ash and baggasse ash as stabilizing material in their studies [2], [3] and [4]. Several researchers have studied the hydraulic conductivity of soils mixed with fly ash and bagasse ash mostly to stabilze the expansive soils and soil-ash mix as admixtures with subgrade soil for pavement constructions [5], [2], [6], [7], [8], [9] and [10]. There are lack of studies on hydraulic conductivity tests conducted on local soils available nearby areas of KNIT Sultanpur mixed with different proportions of fly ash and bagasse ash.

In the present work, a local clayey soil (Soil-1) was collected from Lambhua, Sultanpur and sandy soil (Soil-2) was obtained from field nearby KNIT Sultanpur. Fly.ash was collected from Panki Thermal Power Station, Kanpur and baggase ash was collected from sugar mill Sultanpur. Geotechnical properties of these materials were determined in the soil engineering laboratory of KNIT Sultanpur as per standard methods and procedures. Various proportions of fly ash and baggasse ash were mixed to clayey and sandy soils to observe the changes in behaviour of hydraulic conductivity of the soil ash mixtures. The results of the present work are discussed and presented.

II. MATERIALS & METHODS

2.1 Materials

In the present investigations clay, sand, fly ash and bagasse ash have been used in the various experiments. Local soil-1 was collected from Lambhua Sultanpur from the agricultural field. Soil sample was then oven dried and sieved through 4.75 micron IS sieve Soil -2 was collected from construction site near KNIT Sultanpur. Fly ash was obtained from Panki Thermal Power station Kanpur. Fly ash then oven dried before use in the experiments. Baggase ash was collected from Sugar Mill Sultanpur and was then oven dried and used in all experiments.

2.2 Methods

The hydraulic conductivity of both the soils with and without addition of ashes was determined through falling head permeability test described next.

2.2.1 Falling Head Permeability test

The falling head permeability test determines the permeability or hydraulic conductivity of a material by measuring the time required for water level to fall from a known initial head (h_1) to a known final head (h_2). Fig. 1 shows the laboratory arrangement for the test. The soil specimen is placed inside a tube, and a standpipe is attached to the top of the specimen. Water from the standpipe flows through the specimen. The initial head difference h_1 *at time* $t = 0$ is recorded, and water is allowed to flow through the soil such that the final head difference at time. $t = t$ is recorded as h_2.

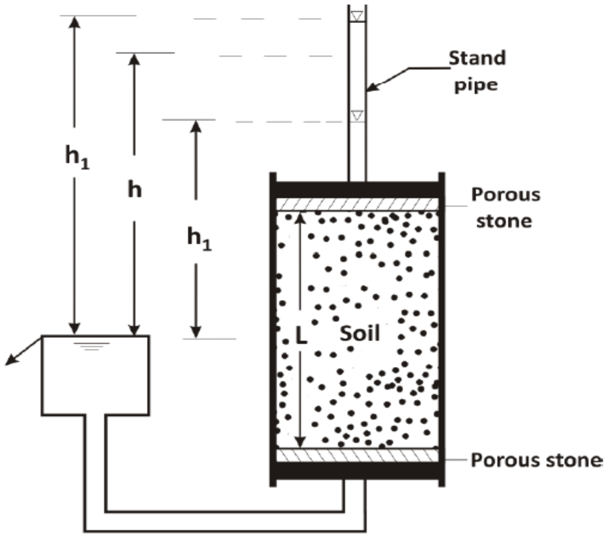

Figure1. A Schematic Representation of Falling Head Permeability Test

The permeability or hydraulic conductivity is then calculated using the following equation:

$$k = \frac{aL}{A\Delta t} \ln \frac{h_1}{h_2} \quad (1)$$

where, k = coefficient of permeability (cm/sec); a = cross-sectional area of the stand pipe. (cm^2); L = length of specimen (cm); A = cross- sectional area of specimen (cm^2); h_1 and h_2 = water levels (cm), and Δt = time required for water falling from head h_1 to h_2 (sec)

The laboratory observations include the measurement of the heads h_1 and h_2 at times t_1 and t_2. The complete details of sample preparation and test procedure followed are adopted from Arora (2009).

III. RESULTS AND DISCUSSION

3.1 Geotechnical properties of soil- 1 and soil-2

The experimentally determined geotechnical characteristics of soil-1 and soil-2 are shown in table 1. From the table 1, it is evident that soil-1 belongs to CL-ML class and soil-2 belongs to class SP. The liquid limit of soil-1 is below 35%. The Proctor test results reveal that OMC and MDD for soil-1 are found as 17.91% and 1.7294gm/cc respectively and that for soil -2 are 10% and 1.92 gm/cc respectively. These characteristics values has been used in further investigations where the soil-1 and soil-2 were mixed with different proportions of fly ash and bagasse ash in testing of variations of hydraulic conductivity of two types of soils under study.

Table1. Geotechnical Characteristics of Soil-1 And Soil-2

SI. No.	Characteristics	Soil-1	Soil-2
1.	Specific gravity	2.79	2.55
2.	Particle size distribution		
	(a) gravel	1.06	0
	(b)sand	10.192	100
	(c) silt &clay	88.702	0
3.	Liquid limit, %	24.1	NA
4.	Plastic limit,%	21.10	NA
5.	Plasticity index	3	NA
6.	Classification of soil	CL-ML	SP
7.	Maximum dry density(gm/cc)	1.7294	1.92
8.	Optimum moisture content (%)	17.91	10
9.	Permeability(m/sec)	$1.877x10^{-7}$	$1.697x10^{-5}$

3.2 Hydraulic Conductivity Test Results of Soil-1 And Soil-2

The hydraulic conductivity of soil -1 and soil -2 have been determined using falling head permeability test as described earlier and the average hydraulic conductivity or permeability of soil -1 is found as 1.877 X 10^{-07} m/sec and that for soil-2 is found as 1.697 x 10^{-5} m/sec.

3.2.1 Data Analysis for Soil-1 with Addition of fly ash in Different Proportions

The soil-1 which is classified as CL- ML, has been randomly mixed with fly ash in nine different proportions: 0, 5, 10, 15, 20, 25, 30, 50, 75%. The hydraulic conductivity test was performed with these proportions of fly ash and data were collected for hydraulic conductivity of soil fly ash mixture. The variations in hydraulic conductivity at various proportions of fly ash are shown graphically in fig 2. From this figure, it is observed that average permeability of soil-1 is seen increasing from 1.877 X 10^{-7} m/s for soil-1 without any addition of fly ash to 7.48 X 10^{-7} m/s at 75% fly ash content by weight. Therefore, in general the hydraulic conductivity is seen increasing with increase in percentage of fly ash upto75% by weight.

It is further evident that there is gradual change in hydraulic conductivity values with increasing fly ash content in soil-1,but at slower rate.

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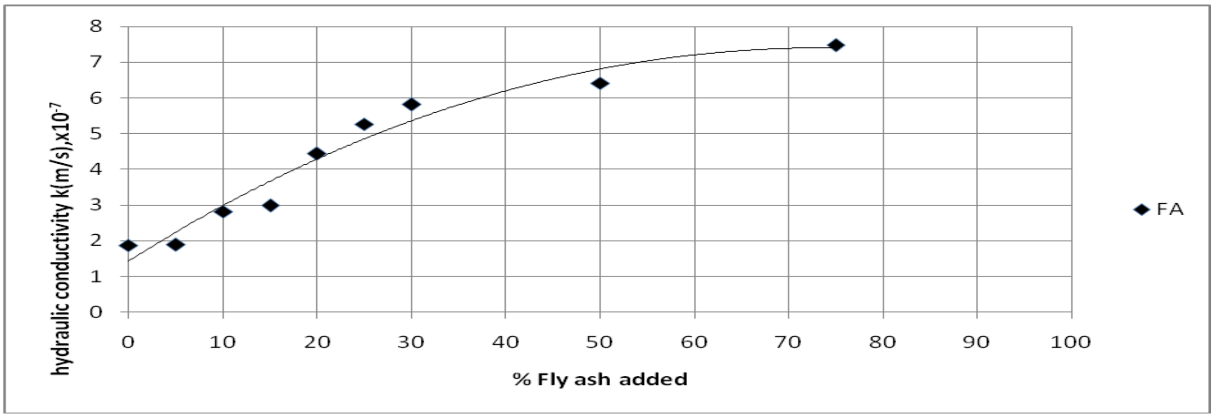

Figure2. Variations in Hydraulic Conductivity of Soil-1 Replaced by fly Ash in Various Proportions

With increase in fly ash content in clay samples, the rate of hydraulic conductivity is seen increasing. Increase in silt particles due to addition of fly ash makes the mixed sample comparatively coarser and hence there is an increase in the hydraulic conductivity values with increase in fly ash content permeability. Fly ash with high percentage content can be mixed in local soil wherever necessary. to enhance the hydraulic conductivity of local clayey soil whichever necessary. such materials may be used for land filling and embankments in the field of geotechnical constructions.

3.2.2 Data Analysis for Soil-1 With Addition of Biogases Ash in Different Proportions

The soil-1 has been randomly mixed with bagasse ash in nine different proportions: 0, 5, 10, 15, 20, 25, 30, 50, 75 (% by weight). The experiments were performed for determination of hydraulic conductivity of mixed soil with these proportions of bagasse ash. The experimental results are plotted in fig. 3.

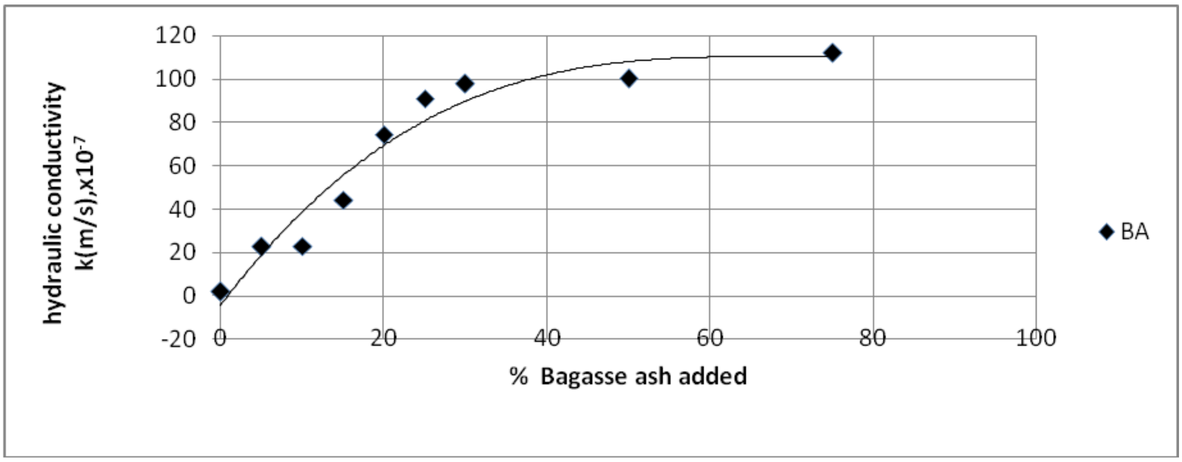

Figure3. Variations in Hydraulic Conductivity of Soil-1 Replaced By Biogases Ash in Various Proportions

From fig. 3, it is evident that the average hydraulic conductivity of soil-1 is observed increasing from 1.877X10^{-7} m/sec without any addition of bagasse ash to 1.12X 10^{-5} m/s at 75% (by weight) of bagasse ash mixed. The possible reason for such behaviour may be that the pozzolanic behaviour of bagasse ash makes the soil coarser than the original clayey soil samples due to the agglomeration of bagasse ash particles within the soil particles. This improvement changes the soil characteristics from clayey to silty in nature. Due to this reason, the hydraulic conductivity is observed increasing, and the rate of hydraulic conductivity increase is relatively bit faster than the rate of hydraulic conductivity increase when mixed with fly ash. Therefore, in general the hydraulic conductivity is observed increasing with increase in bagasse ash content and saturates almos at about 75% bagasse ash content.

3.2.3 Data Analysis for Soil-2 With Addition of Fly Ash in Different Proportions

The experimental results of hydraulic conductivity of soil-2 with fly ash mixed in various proportions are shown in fig. 4. From fig. 4, it is observed that average hydraulic conductivity of soil-2 is observed decreasing from 1.697 X 10^{-05} m/s without fly ash to 4.40 X10^{-6} m/s with fly ash content, 75%. Therefore, in general the hydraulic conductivity is decreasing with increase in fly ash content.

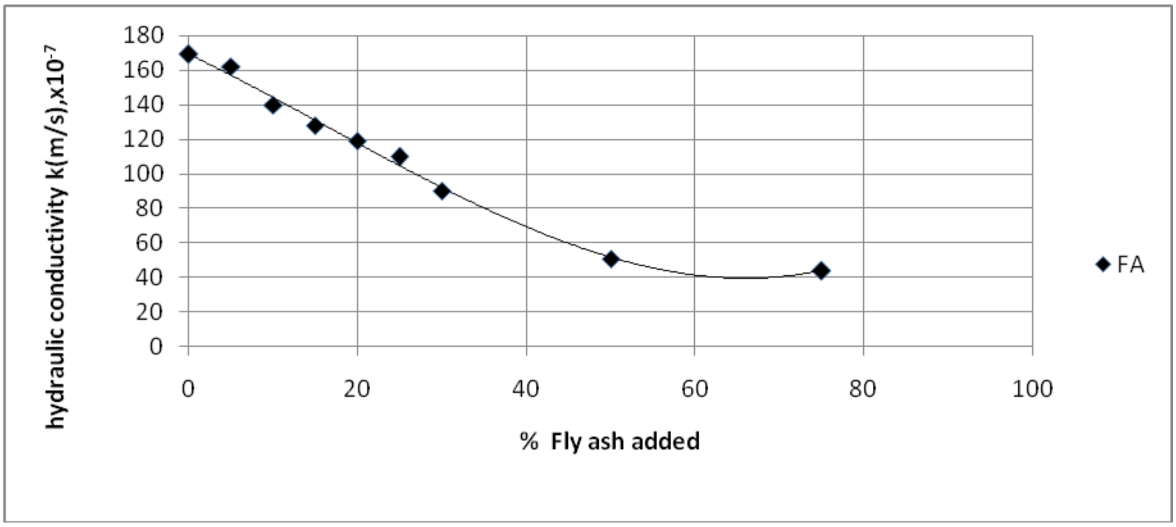

Figure4. Variations in Hydraulic Conductivity of Soil-2 Replaced By Fly Ash in Various Proportions

3.2.4 Data Analysis for Soil-2 With Addition of Fly Ash in Different Proportions

The experimental results of hydraulic conductivity of soil-2 -bagasse ash mixtures are shown in Fig. 5. From Fig. 5, it is evident that the hydraulic conductivity of soil is continuously decreasing with increase in bagasse ash content (1.697X 10^{-05} at 0% to 8.86X10^{-07}m/sec. at 75% bagasse ash content). But the rate of decrease is relatively faster than in the soil mixed with fly ash.

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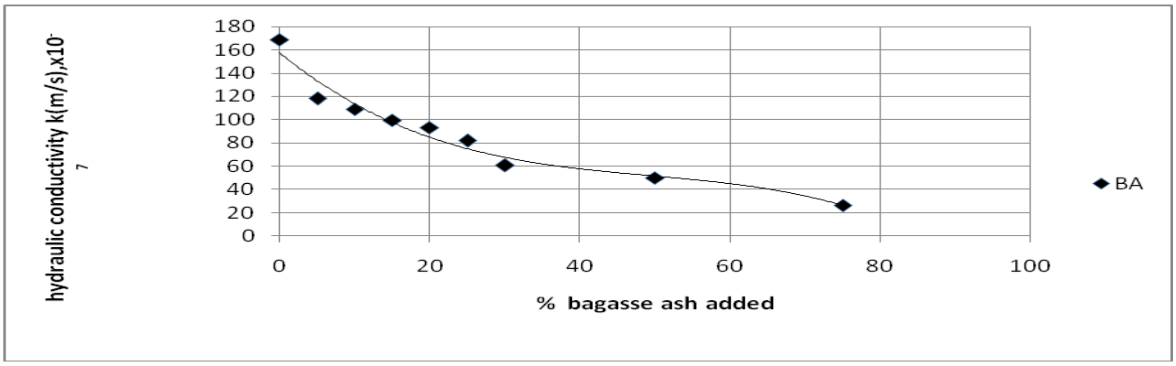

Figure5. Variations in Hydraulic Conductivity of Soil-2 Replaced By Biogases Ash in Various Proportions

3.3. Comparison of Results

The results obtained in the study are further analyzed and compared for hydraulic conductivity variations when both the soils are mixed with different proportions of fly ash and bagasse ash and are shown in Table 2.

Table 2. Hydraulic Conductivity of Soil-1 And Soil-2 Replaced with Different Proportions of FA and BA

s. no	% ash content	Hydraulic conductivity of soil-1 mixed with		Hydraulic conductivity of soil-2 mixed with	
		Fly ash	bagasse ash	Fly ash	Bagasse ash
1	0	$1.877X10^{-07}$	$1.877X10^{-07}$	$1.697X10^{-05}$	$1.697X10^{-06}$
2	5	$1.88X10^{-07}$	$2.26X10^{-06}$	$1.62X10^{-05}$	$1.18X10^{-05}$
3	10	$2.82X10^{-07}$	$2.99X10^{-06}$	$1.40X10^{-05}$	$1.09X10^{-05}$
4	15	$2.98X10^{-07}$	$4.42X10^{-06}$	$1.28X10^{-05}$	$9.97X10^{-06}$
5	20	$4.44X10^{-07}$	$7.45X10^{-06}$	$1.19X10^{-05}$	$9.34X10^{-06}$
6	25	$5.27X10^{-07}$	$9.10X10^{-06}$	$1.10X10^{-05}$	$8.19X10^{-06}$
7	30	$5.82X10^{-07}$	$9.76X10^{-06}$	$9.02X10^{-06}$	$6.08X10^{-06}$
8	50	$6.42X10^{-07}$	$1.00X10^{-05}$	$5.09X10^{-06}$	$4.99X10^{-06}$
9	75	$7.48X10^{-07}$	$1.12X10^{-05}$	$4.40X10^{-06}$	$2.655X10^{-06}$

A comparison of the hydraulic conductivity variations for both the soils with different proportions of fly ash and bagasse ash are also plotted in fig. 6.

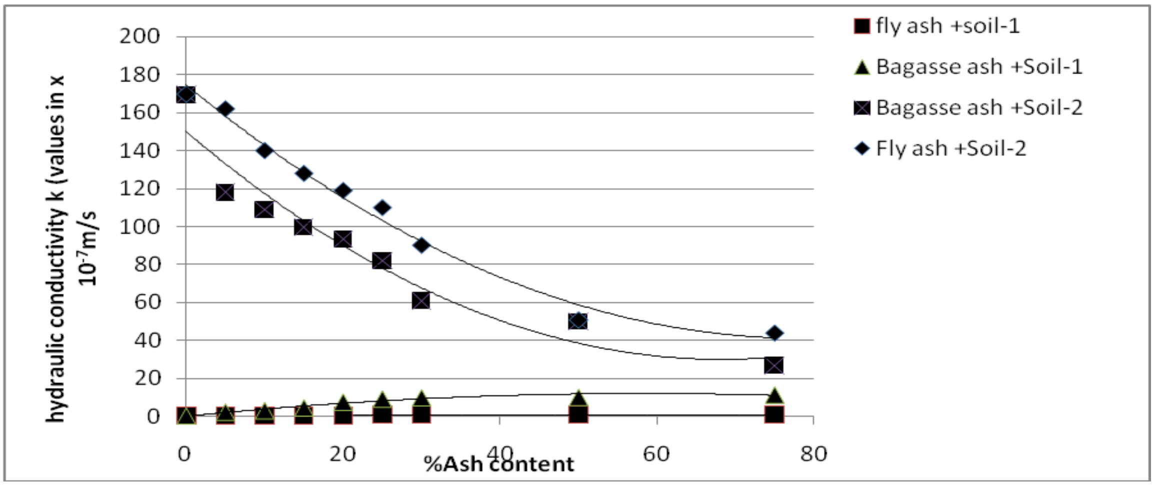

Figure 6. Comparison of Hydraulic Conductivities of Soil-1 and Soil-2 Replaced with FA and BA in Various Proportions

From Table 2 and The Fig. 6, Following Observations are Made.

1. It can be seen that for soil-1 when FA is added, the hydraulic conductivity is increased from 1.877 x10 $^{-07}$ m/s for without any FA content to 7.48 x10 $^{-07}$ at 75 % FA content. Therefore, in general the hydraulic conductivity of soil-fly ash mixture is observed increasing with increasing FA content and following a second order polynomial trend. But the rate of increase is relatively slow.
2. It can be further seen that for soil-1mixed with BA, the hydraulic conductivity is increased from 1.877 x10^{-07} m/s without any BA content to 1.12 X 10^{-05} m/s at 75 % BA content. The rate of increase is relatively faster following a second order polynomial behavior. The rate of increase in hydraulic conductivity is relatively much faster in comparison to the soil-1 when replaced with fly ash.
3. It is evident that when soil-2 (sand) is replaced by FA, the hydraulic conductivity of soil -2 is seen decreasing throughout but the rate of decrease is slower up to 30%(by weight) and then decrease rate is high up to 75% FA content.
4. It is further seen that when soil-2 (sand) is replaced by BA, the hydraulic conductivity of soil -2 is again seen decreasing throughout but the rate of decrease is higher as comparison to the soil replaced by FA, the hydraulic conductivity is decreased from 1.697 X10^{-05} at 0% BA content to 2.655 X 10^{-06} m/sec. at 75% BA content.
5. From fig. 6, it is evident that the variations of hydraulic conductivity of soil-1 replaced by fly ash and bagasse ash follow a more or less similar decreasing trend of hydraulic conductivity with increasing percentage of ash contents. On the other hand, a reverse trend is seen with soil-2 mixed with fly ash and bagasse ash showing an increasing trend of hydraulic conductivity with increase in ash contents following a second order polynomial trend from the fig. 6, it can be postulated that the increase in silt particles after addition of fly ash makes the mixed soil comparatively coarser and hence increase the hydraulic

conductivity. Fly ash with high percentage content can be mixed in local soil under study and may be used for land filling and embankments in the geotechnical constructions.

IV. CONCLUSIONS

Present study reveals the following important conclusions.

1. The analysis of the characteristics of both the soil through particle size distribution, it is found that soil-1 belongs to CL-ML class while soil-2 is poorly graded sand (SP).
2. Proctor test results reveal that OMC and MDD for soil-1 are 17.91% and 1.7294 g/cc respectively and for soil-2, 10% and 1.92 gm/cc respectively.
3. The specific gravity of soil-1 and soil-2 was found as 2.79 and 2.55 respectively
4. The hydraulic conductivity test results show that the permeability value of 1.877×10^{-7} m/s for soil-1 and 1.697×10^{-5} m/s for soil-2.
5. For soil-1 when replaced with FA, the hydraulic conductivity is increased from 1.877×10^{-07} m/s for without any FA content to 7.48×10^{-07} at 75 % FA content at slower rate and follows a second order polynomial trend.
6. For soil-1mixed with BA, the hydraulic conductivity is increased from 1.877×10^{-07} m/s without any BA content to 1.12×10^{-05} m/s at 75 % BA content at relatively faster rate and following a second order polynomial behavior.
7. In case of soil-2 (sand) replaced by FA, the hydraulic conductivity of soil -2 is seen decreasing throughout but the rate of decrease is slower up to 30%(by weight) and then decrease rate is relatively faster upto 75% of FA content.
8. It is inferred that when soil-2 (sand) is replaced by BA, the hydraulic conductivity of soil -2 is again seen decreasing throughout but the rate of decrease is higher as comparison to the soil replaced by FA, from 1.697×10^{-05} at 0% BA content to 2.655×10^{-06} m/sec. at 75% BA content.
9. It is further concluded that the variations of hydraulic conductivity of soil-1 replaced by fly ash and bagasse ash follow a more or less similar decreasing trend of hydraulic conductivity with increasing percentage of ash contents. On the other hand, a reverse trend is seen with soil-2 mixed with fly ash and bagasse ash showing an increasing trend of hydraulic conductivity with increase in ash contents.

Thus, the comparison of hydraulic conductivity variations reveals that proper attention need to be paid in modifying the hydraulic conductivity of local soils as per the requirements in the field applications while using waste materials such as fly ash and bagasse ash in suitable proportions.

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